

**NASA'S SIMULANT DEVELOPMENT PROGRAM EVOLUTION AND OVERVIEW** Carole McLemore<sup>1+</sup>, John Fikes<sup>2</sup>, Charles Owens<sup>3\*</sup>, Doug Rickman<sup>4</sup>, <sup>1</sup>NASA, Marshall Space Flight Center, Huntsville, AL 35812 [carole.a.mclemore@nasa.gov](mailto:carole.a.mclemore@nasa.gov), <sup>2</sup>NASA, Marshall Space Flight Center [john.c.fikes@nasa.gov](mailto:john.c.fikes@nasa.gov), Huntsville, AL 35812 <sup>3</sup>Teledyne Brown Engineering, Huntsville, AL 35805 [charles.e.owens@nasa.gov](mailto:charles.e.owens@nasa.gov), <sup>4</sup>Marshall Space Flight Center, National Aeronautics and Space Administration, 320 Sparkman Drive, Huntsville, AL 35805 [doug.rickman@nasa.gov](mailto:doug.rickman@nasa.gov), \*Corresponding Author, <sup>+</sup>Point of contact for additional information.

**Introduction:** Since its origination under NASA's previous Human System Research and Technology program, the Lunar Simulant Development Program has undergone several changes. NASA recognized as early as the Apollo Program, and even more so as a result of the Apollo missions, that a viable dust and lunar simulant program is critical to the success of its space exploration goals. Unfortunately, this program has suffered the same problems that all programs share from time to time including uncertain budgets, shifting of priorities, and schedule fluctuations. To compound the problem, the process for developing simulants is being redefined and is not a trivial pursuit. Before now, NASA had not attempted to develop a suitable standard simulant since the 1990s when JSC-1 was produced. Although several other simulants have been developed by various groups both before and after the production of JSC-1, JSC-1 had become the de facto standard even though it has some limitations. The development and production of new simulants will address some of these limitations by starting with an assessment of NASA's needs and understanding the required processing in order to make these simulants.

**Understanding NASA's Needs and Requirements:** The 1989 workshop report entitled *Workshop on Production and Uses of Simulated Lunar Materials* [1] and the *Lunar Regolith Simulant Materials: Recommendations for Standardization, Production, and Usage*, NASA Technical Publication [2], both identified and reinforced a need for a set of standards and requirements for the production and usage of lunar simulant materials. As NASA first made attempts to document what a "standard" simulant might be based on current knowledge of lunar materials, it became obvious that translating the nature of lunar materials into something that is "testable" to a requirement was not going to be a trivial task. Also revealed was the fact that there is no "one-size fits all" simulant. Different users require different properties which need to be replicated in the simulants for various scientific and engineering purposes. At the same time, it also became apparent that to create a simulant with reasonable lunar characteristics required an acute understanding of mineralogy, geo-technical, and chemical properties of both dust and

lunar regolith on the moon, but also the materials on Earth from which the simulants will be made.

**A Paradigm Shift in the Simulant Development Program:** During the summer of 2006, NASA set out to understand terrestrial materials and the processes to extract these materials from the ground as well as the effort it would take to process these materials. NASA was able to engage the services of the U.S. Geological Survey (USGS) to assist on this task. Not only does the USGS bring some of the best geologists in the world with utmost knowledge about the Earth's materials to the task, but they have also been able to provide NASA unprecedented access to the mining and milling industries. NASA focused on obtaining the basic knowledge required to understand the complexity of simulant production. The aspects and challenges of material selection, mineralogy, material phases and relationships, and materials production all started to come together. It was realized at this point that basic program concepts related to developing simulants in the past were needing to change. As more was learned and innovative ideas surfaced, an entirely new method for developing and producing simulants emerged. With this revelation and acknowledgement, a new paradigm in dust and lunar simulant development was born.

**Changes in the Simulant Development Program:** In order to successfully implement this new method, NASA realized that the following would have to occur: simulant needs for various users and their research purposes would have to be understood, and simulant requirements would have to change to reflect the basic properties of materials required to meet the users' needs. A way to compare an existing simulant or newly produced simulant against the required properties was needed. This, in turn, would allow programs needing simulants to compare and select the correct simulants for their tasks. NASA also had to find a way to allow scientists and engineers to utilize other simulants produced by other entities, but still maintain some type of baseline comparisons for research results to be equitably made. A logical and unambiguous method was needed to certify a simulant for use on a NASA program allowing for variations in production methods. This method utilizes software algorithms in the form of Figures of Merit which allows comparison of properties of a

known reference material (i.e., Apollo samples) to a simulant to assist the user in determining if a particular simulant is adequate for his/her needs. In order to develop these references used to compare simulant properties against, more data is going to be needed from the current Apollo samples. Gaps in required Lunar regolith characterization data are being identified and are being acquired with the assistance of the JSC/Astromaterials and Research Exploration Systems office.

**Benefits to NASA Programs:** Shortly after embarking on a path to implement the required changes to the program, several benefits of the new approach became apparent. First, NASA was now on a path to developing simulants that satisfy a broad range of applications including equitable comparisons of research efforts. By providing these simulants and the means to compare the simulants against reference material, NASA is reducing risk and cost to the Vision for Space Exploration by providing appropriate simulants to test hardware and systems on Earth prior to returning to the moon for long-term operations. The knowledge gained and the processes already in place for developing lunar simulants will be leveraged as we begin the process of defining and developing dust simulants and eventually Mars simulants.

**Program Customers:** The NASA Simulant Program managed by Carole McLemore at MSFC currently supports the In Situ Resource Utilization Project managed by Jerry Sanders at the Johnson Space Center and the Dust Management Project managed by Mark Hyatt at the Glenn Research Center. Simulant has also been developed and/or delivered to support the HQ Centennial Challenge program, Agency Investment Opportunities, and educational outreach.

**References:** [1] D. S. McKay, James D. Blacic, *Workshop on Production and Uses of Simulated Lunar Materials*, LPI Technical Report Number 91-01. [2] Sibille L., Carpenter P., Schlagheck R., and French R. (2005) *Lunar Regolith Simulant Materials: Recommendations for Standardization, Production, and Usage*, NASA Technical Publication NASA/TP-2006-214605.